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PERFORMANCE CHARACTERISTICS OF AUTOMOTIVE ENGINES IN THE UNITED STATES

First Series--Report No. 12

1975 Perkins Diesel 247 CID (4.0 Liters), F. I.

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INTERIM REPORT

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Washington DC 20590

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16. Abstract

Experimental data were obtained in dynamometer tests of a 1975 Perkins 247-CID diesel engine to determine fuel consumption and emissions (hydrocarbon, carbon monoxide, oxides of nitrogen) at steady-state engine-operating modes. The objective of the program is to obtain engine-performance data for estimating emissions and fuel economy for varied engine service and duty. The intent of the work is to provide basic engine characteristic data required as input for engineering calculations involving ground transportation.

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PREFACE

This report was prepared by the U.S. Department of Energy, Bartlesville Energy Research Center, for the U.S. Department of Transportation, Transportation Systems Center, Energy Technology Branch, Cambridge MA. Presented are results of experimental work performed to obtain information on performance characteristics of an engine suitable for use in automobiles sold in the United States. The engine used in this work is one of a series of 23 engines to be tested in the current program.

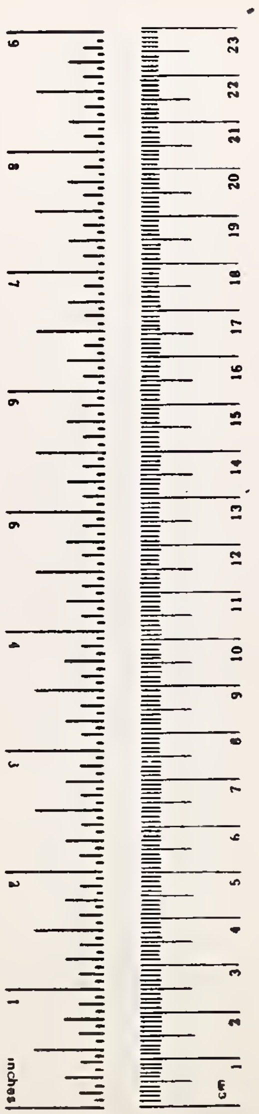
This project is funded by The National Highway Traffic Safety Administration, Office of Research and Development, Office of Passenger Vehicle Research, Technology Assessment Division.

Ralph G. Colello and James A. Kidd, Jr., of the U.S. Department of Transportation, Transportation Systems Center, are the technical monitors.

METRIC CONVERSION FACTORS

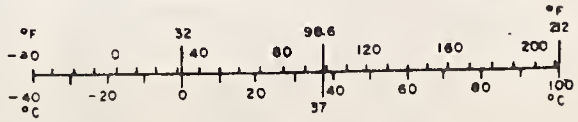
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



1. INTRODUCTION

This report presents data acquired from tests of a Perkins 247-CID diesel engine. The test results are sufficient to establish steady-state maps for engine performance, fuel consumption, and emission rates (carbon monoxide, unburned hydrocarbon, and oxides of nitrogen) over the entire operating range of the engine.

The objective of this program is to provide engine performance data for estimating emissions and fuel economy for varied engine service and duty. The intent of this work is to provide basic engine characteristic data required as input for engineering calculations involving ground transportation.

2. ENGINE TEST REPORT

General engine specifications for the Perkins 247-CID diesel engine are listed in table 1. A single batch of No. 2 diesel fuel was used throughout the breakin (table 2) and tests; an analysis of the fuel is given in table 3.

The engine breakin and tests were conducted with a new mean-tolerance engine mounted on a test stand and coupled to an eddy-current dynamometer. The engine was complete except for a fan (a cooling tower was used in place of the radiator). The alternator was used, but was not wired into the charging system.

The engine breakin consisted of 24 hours of operation at various speeds and loads. The total engine-operating time at the completion of testing was approximately 230 hours. The period of testing ran from 2 through 8 October 1975.

Test data were collected at the following steady-state modes:

Speeds: 1,200; 1,600; 1,900; 2,100; 2,400; 3,000; 3,600 rpm

Loads: 0, 5, 10, 25, 50, 75, 80, 90, 100 pct of full load
(repeated at 0, 5, 10, 25, 50, 75 pct of full load)

Idle speed loads: 0, 1, 2 bhp (repeated at 0 bhp)

Total number of test modes....................	68
Total number of repeats.......................	45
Total number of tests.........................	113

The following data were recorded for each test:

Test number
Date
Barometric pressure, mm Hg
Dew point, °F
Inlet air temperature, °F
Speed, rpm
Torque, lb-ft -- BLH strain gage; Daytronics indicator
Fuel rate, lb/hr -- FLO-TRON linear mass flowmeter
Throttle position -- deg
CO, ppm -- Beckman NDIR
CO_2, pct -- Beckman NDIR
HC, ppmC -- Custom built heated FID
NO_x, ppm -- Thermo-Electron chemiluminescent detector
Oil temperature, °F

Oil pressure, psi
Coolant temperature, °F
Exhaust temperature, °F
Exhaust pressure, in. H_2O
Smoke, pct opacity -- PHS smokemeter
Airflow, lb/min -- Meriam laminar flow element.

The computed data include absolute humidity, power, exhaust flow rate, and emission rates of carbon monoxide (CO), unburned hydrocarbons (HC), and oxides of nitrogen (NO_x) in grams per hour. The following equations were applied in the computations:

$$H_2O\ (\text{mm Hg}) = \exp\left[12.02\left(\frac{\text{Dew pt. } (°F) - 1.4}{\text{Dew pt. } (°F) + 212}\right)\right],$$

$$\text{Humidity (grains } H_2O/\text{lb dry air}) = H = \frac{(4348)(H_2O)}{\text{Baro} - H_2O},$$

$$\text{Power (bhp)} = \left(\frac{\text{Speed x Torque}}{5252}\right)\left(\frac{736.6}{\text{Baro} - H_2O}\right)\left(\frac{t_{air} + 460}{545}\right)^{0.7},$$

$$\text{Exhaust flow (lb/min)} = \text{Air flow (lb/min)} + \frac{\text{Fuel flow (lb/hr)}}{60},$$

$$\text{Mass CO} = \begin{pmatrix}\text{exhaust}\\ \text{flow}\\ \text{rate}\end{pmatrix}\begin{pmatrix}\text{concentration}\\ \text{of}\\ \text{CO}\end{pmatrix}\left(\frac{\text{Mol. Wt. of CO}}{\text{Mol. Wt. of exhaust}}\right)\begin{pmatrix}\text{correction}\\ \text{for water}\\ \text{removal}\end{pmatrix},$$

$$\text{Mass CO} = 0.0263\ (\text{exhaust rate})\ (\text{ppm CO})\left[\frac{1}{1 + 0.03\ CO_2\left(\frac{CO + CO_2}{CO + 3CO_2}\right)}\right],$$

$$\text{Mass HC} = 0.0132\ (\text{exhaust rate})\ (\text{ppmC HC}),$$

$$\text{Mass } NO_x = 0.0432\ (\text{exhaust rate})\ (\text{ppm } NO_x)\left[\frac{1}{1 + 0.03\ CO_2\left(\frac{CO + CO_2}{CO + 3CO_2}\right)}\right](K_H),$$

where K_H is the humidity correction factor, and

$$K_H = \frac{400}{475 - H}.$$

3. DISCUSSION OF TEST RESULTS

Brake horsepower, torque, and brake specific fuel consumption are shown plotted against engine speed (at full rack conditions) in figure 1. The maximum brake horsepower and peak torque values generally agree with those quoted in table 1. Fuel consumption rate was repeatable for various power output levels at a given speed (figure 2) and is nearly a linear function of power at any given engine speed. Emission rates of CO, HC, and NO_x as a function of power (figures 3 through 5) show relationships similar to those of other diesel engines equipped with the swirl combustion chamber and having high-speed capability. Exhaust-stream opacity showed higher levels of smoke when the engine was not producing any brake power (figure 6).

4. CONCLUSIONS

The repeatability of emission rates, fuel consumption, smoke levels, and engine performance was satisfactory for the purposes of these tests.

The repeatability of emis
levels, and engine performance
these tests.

TABLE 1. MANUFACTURER'S ENGINE SPECIFICATIONS

Displacement, in	247.3
Maximum power, bhp @ 3,600 rpm	98
Maximum torque, ft-lb @ 2,100 rpm	164
Configuration	in-line 6 cylinder, vertical
Bore, in	3.622
Stroke, in	4.00
Combustion system	swirl chamber
Compression ratio	21.0
Firing order	1-5-3-6-2-4
Injection pressure, psi	1,920
Injection timing, °BTDC	4
Block material	cast iron
Head material	cast iron
Number of crankshaft main bearings	7
Number of compression rings/piston	2
Number of oil rings/piston	1
Cam drive	gear
Engine weight, lb	850
Valve clearance (warm):	
Intake, in	0.012
Exhaust, in	0.012
Valve port size:	
Intake, in	1.45
Exhaust, in	1.24
Valve timing:	
Intake opens, °BTC	14
Intake closes, °ABC	44
Exhaust opens, °BBC	48
Exhaust closes, °ATC	10

TABLE 2. ENGINE BREAK-IN SCHEDULE

Engine speed, rpm	Torque, lb-ft	Time in mode, hr
1,400	14	1
1,800	14	1
1,800	28	2
2,200	28	2
2,200	43	2
2,500	43	2
2,500	57	2
2,900	57	2
2,900	71	2
3,100	71	2
3,100	85	2
3,200	85	1
3,200	99	1
3,400	99	1
3,600	114	1

TABLE 3. FUEL ANALYSIS

Fuel No.	7558
Distillation, °F:	
10 pct evaporated	407
50 pct "	487
90 pct "	579
End point "	618
API gravity, deg	36
FIA analysis, pct:	
Aromatics	32
Olefins	4
Paraffins	64
Sulfur, pct	0.26

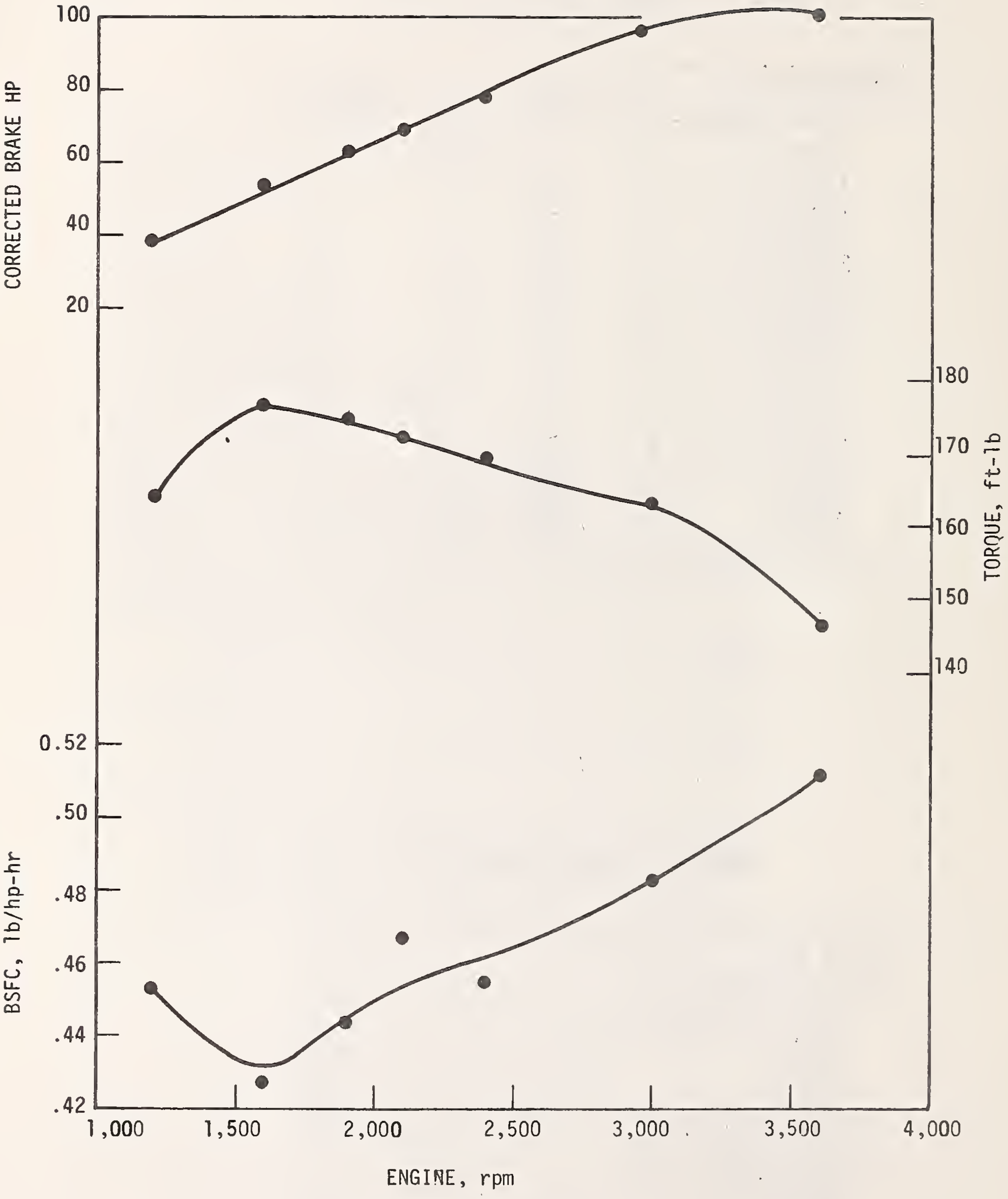


FIGURE 1. Brake Specific Fuel Consumption, Torque, and Brake Horsepower versus Engine rpm at Wide-Open Throttle--Perkins Diesel 247-CID Engine.

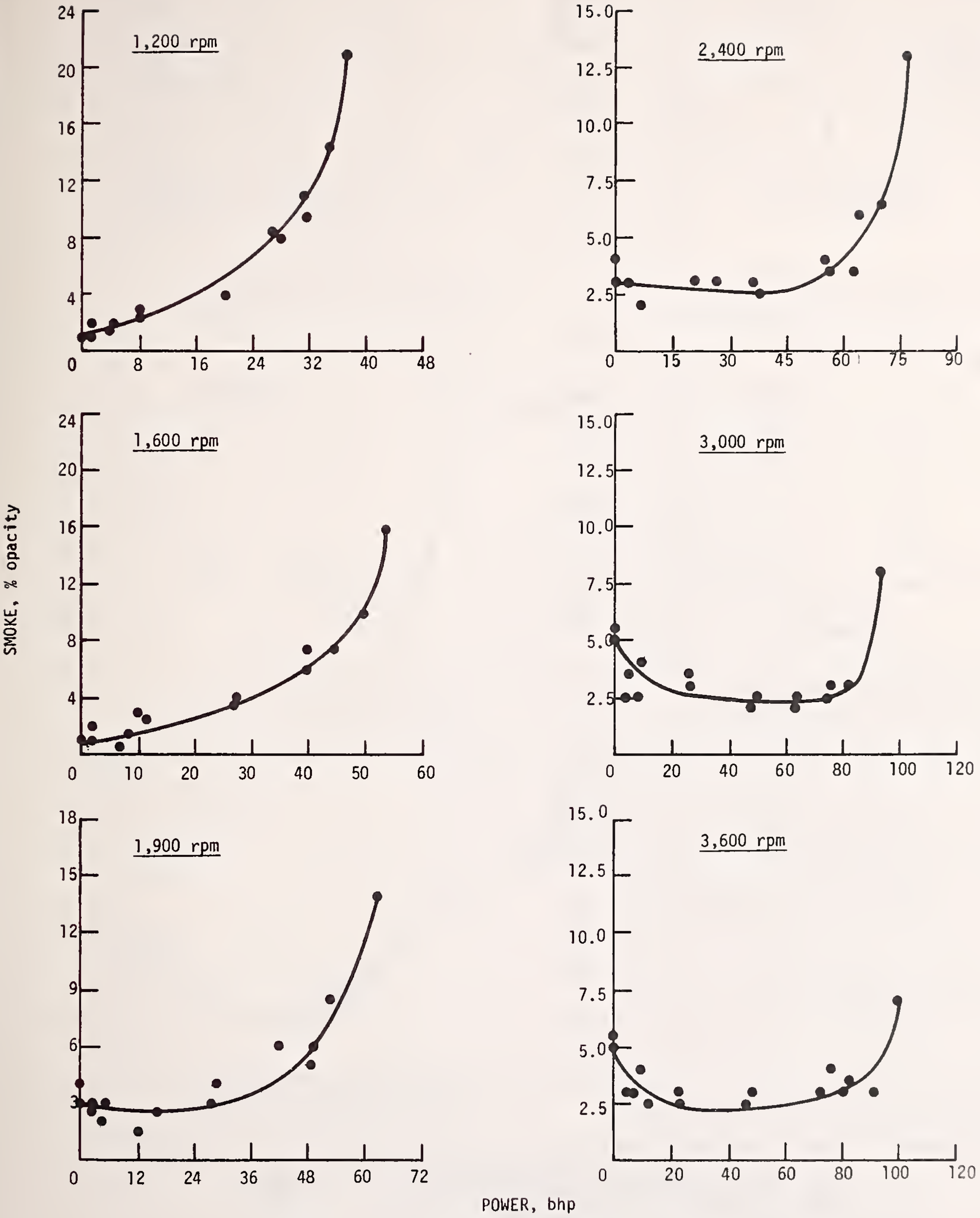


FIGURE 2. Emissions of Smoke versus Power at Various Speed and Load Conditions--Perkins Diesel 247-CID Engine.

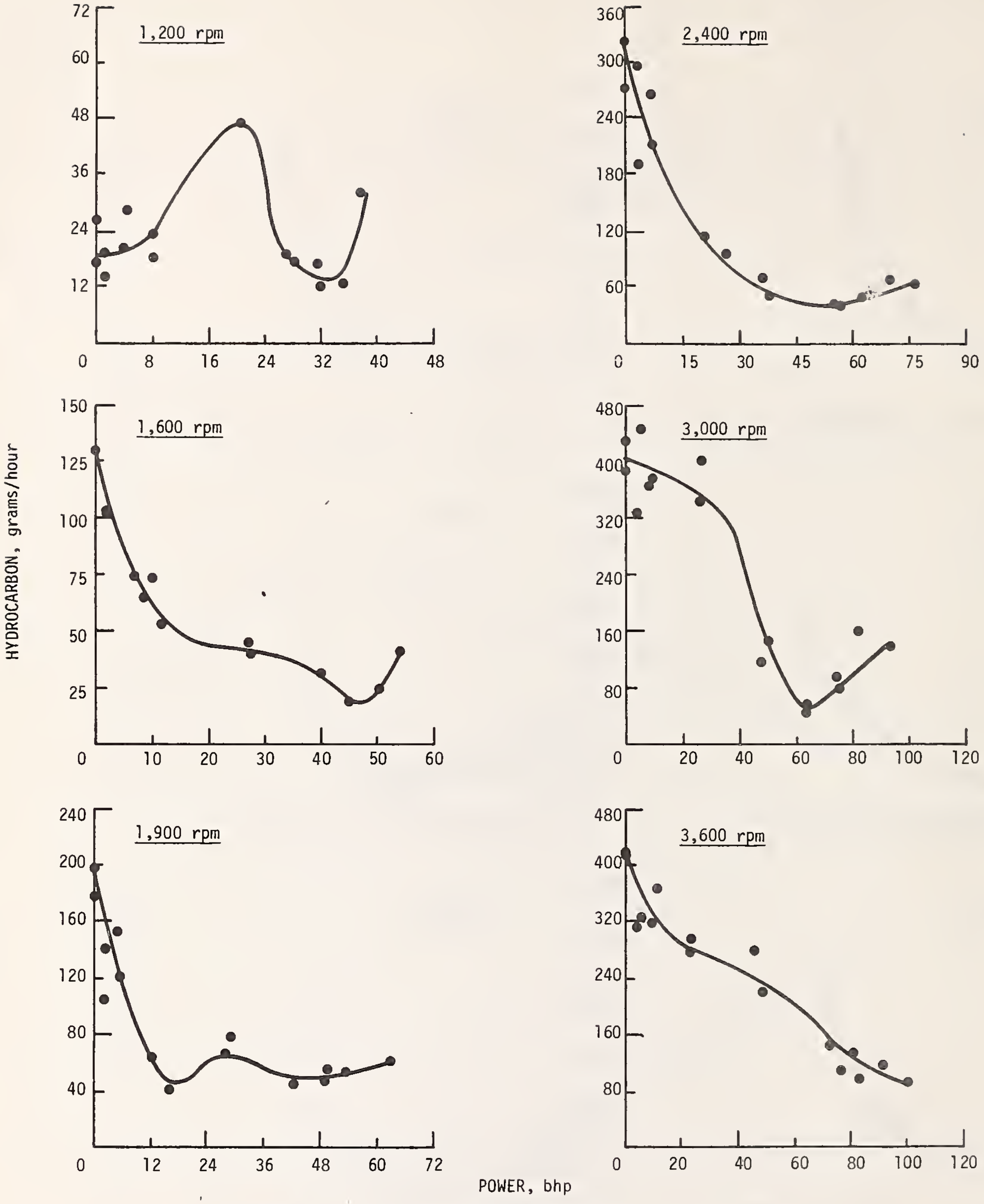


FIGURE 3. Hydrocarbon Emissions versus Power at Various Speed and Load Conditions--Perkins Diesel 247-CID Engine.

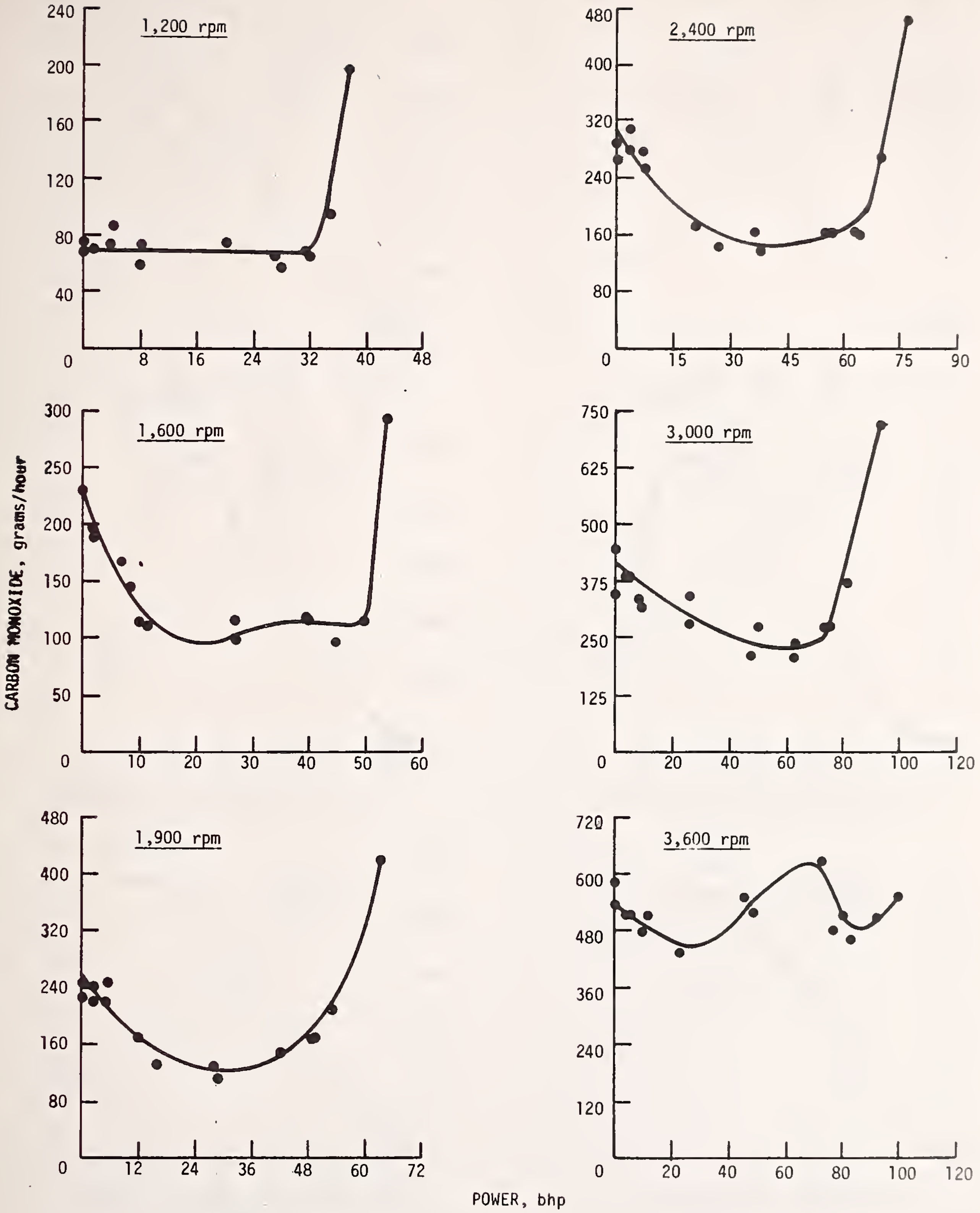


FIGURE 4. Carbon Monoxide Emissions versus Power at Various Speed and Load Conditions--Perkins Diesel 247-CID Engine.

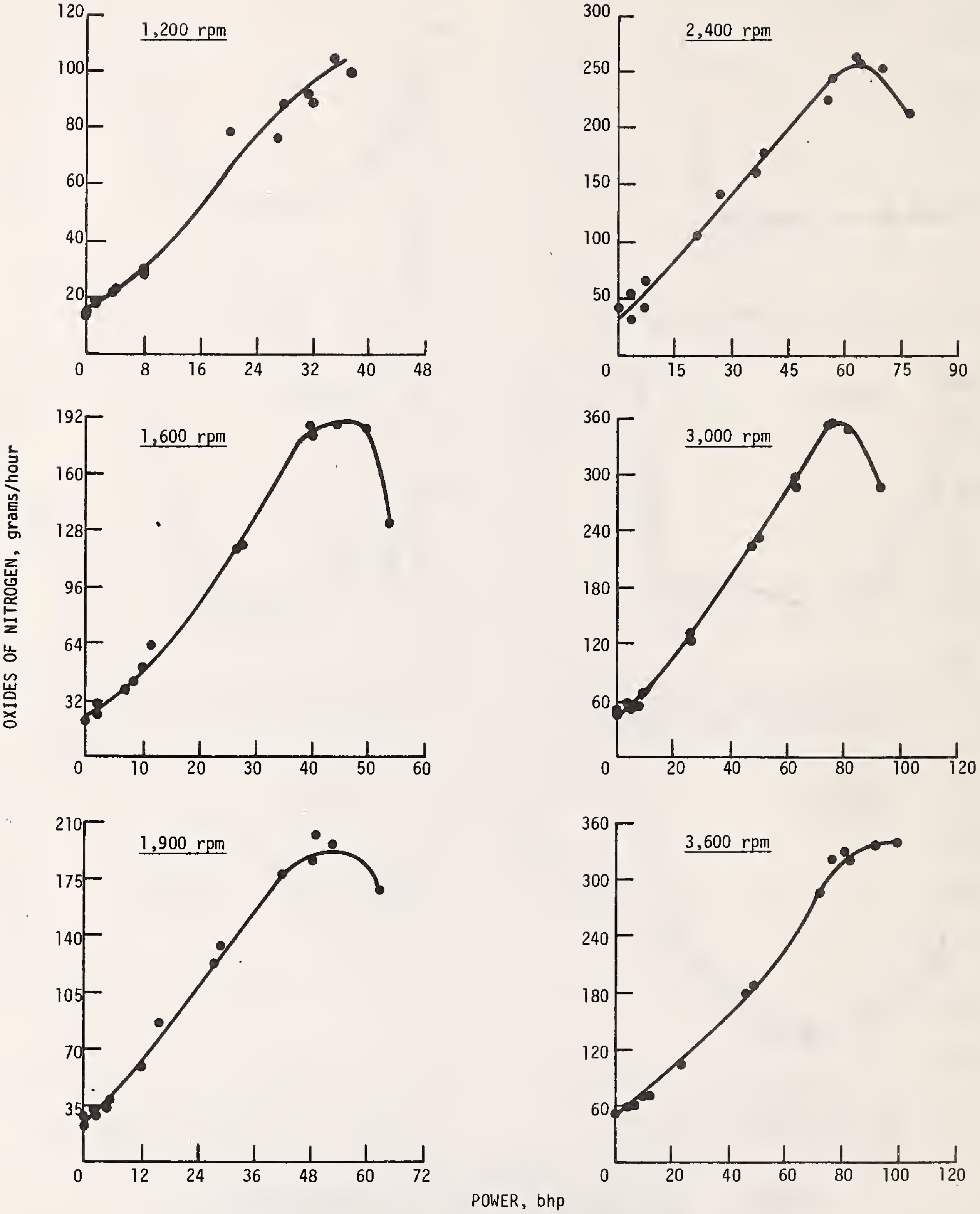


FIGURE 5. Oxides of Nitrogen Emissions versus Power at Various Speed and Load Conditions--Perkins Diesel 247-CID Engine.

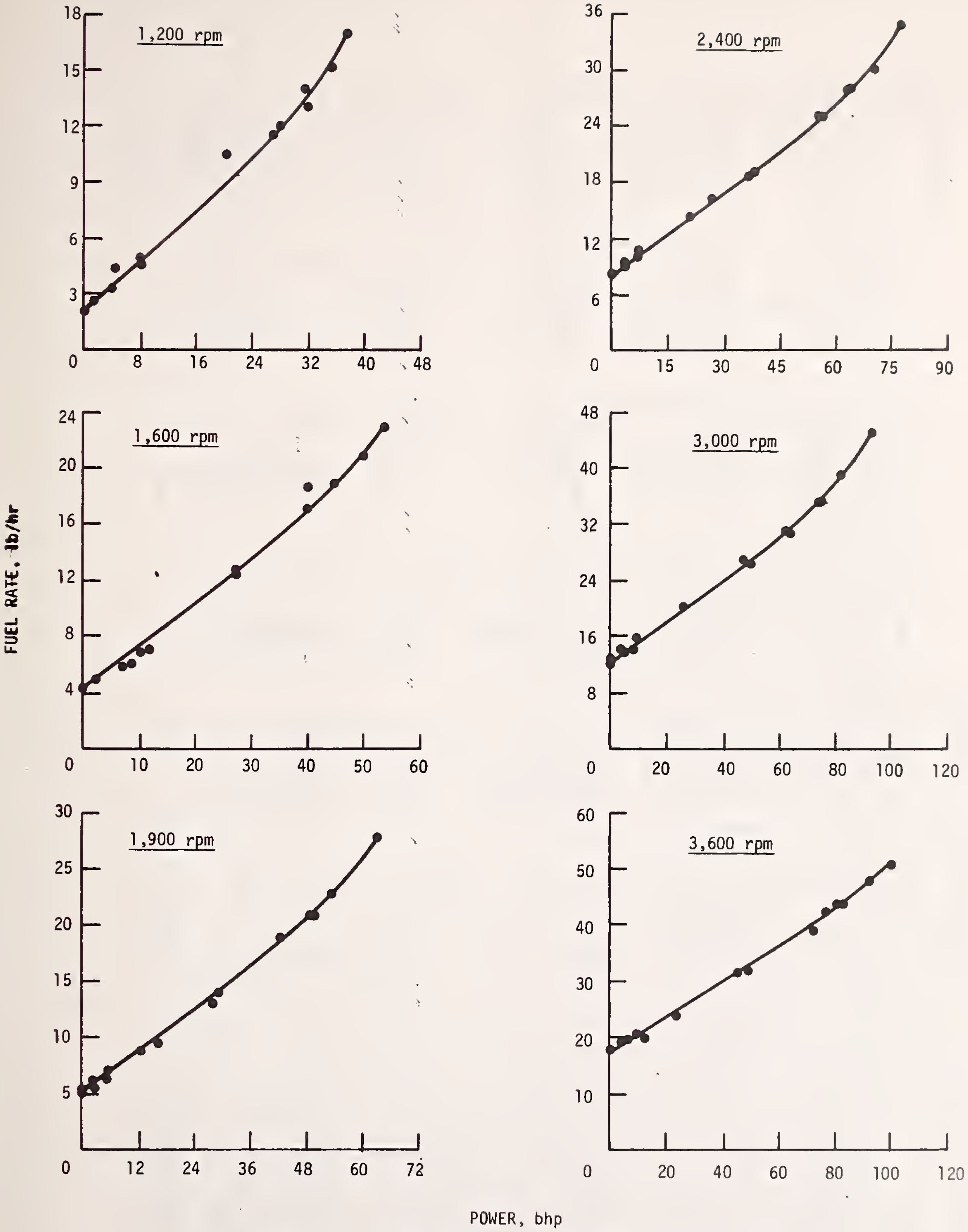


FIGURE 6. Fuel Rate versus Power at Various Speed and Load Conditions--Perkins Diesel 247-CID Engine.

Engine...................... Perkins diesel, 247-CID
Fuel........................ 7558

Test Number	1	2	3	4	5	6
Test Date	10/ 8/75	10/ 8/75	10/ 8/75	10/ 8/75	10/ 8/75	10/ 2/75
Barometer, mm Hg	741.4	741.4	741.4	741.4	741.4	755.5
Humidity, grains/lb	70	70	70	70	70	58
Temperature, F	86	84	84	89	87	88
Engine speed, rpm	700	700	700	700	700	1200
Torque, lb-ft	0.0	6.0	0.0	18.0	0.0	165.0
Power, bhp*	0.0	.8	0.0	2.4	0.0	37.5
Fuel rate, lb/hr	1.5	1.8	1.5	1.0	1.5	17.0
Throttle angle, deg	0.0	0.0	0.0	0.0	0.0	26.0
Concentrations, dry basis:						
CO, %	.0200	.0200	.0200	.0600	.0200	.1400
CO2, %	2.47	2.74	2.97	2.32	2.21	10.17
O2, %						
HC, ppmC	104	81	104	13	149	455
NOx, ppm	150	170	183	110	125	450
Emission rates, g/hr:						
CO	15.4	15.4	14.9	45.9	15.5	196.1
HC	4.0	3.1	3.9	.5	5.8	32.0
NOx**	18.7	21.3	22.1	13.7	15.7	99.4
Oil temperature, F	167	166	166	176	170	173
Oil pressure, psi	39	38	38	34	38	45
Coolant temperature, F	186	190	193	184	185	191
Exhaust temperature, F	214	215	227	308	217	930
Exhaust pressure, in H2O	.4	.3	.3	.4	.4	17.0
Exhaust flow, lb/min	2.99	3.01	2.91	2.98	3.00	5.87
Smoke, % opacity	3.0	3.0	3.0	3.0	3.0	21.0

* Corrected - SAE J816b.

** Corrected for humidity.

Engine: Perkins diesel, 247-CID
Fuel: 7558

Test Number	7	8	9	11	12	13
Test Date	10/ 7/75	10/ 6/75	10/ 8/75	10/ 8/75	10/ 6/75	10/ 7/75
Barometer, mm Hg	746.0	746.9	741.4	741.4	746.9	746.0
Humidity, grains/lb	72	69	70	70	69	72
Temperature, F	88	89	86	82	89	87
Engine speed, rpm	1200	1200	1200	1200	1200	1200
Torque, lb-ft	151.5	138.0	135.7	121.9	116.8	88.2
Power, bhp*	35.0	31.8	31.4	28.1	26.9	20.3
Fuel rate, lb/hr	15.2	13.0	14.0	12.0	11.5	10.5
Throttle angle, deg	6.2	5.9	5.2	5.2	5.2	4.2
Concentrations, dry basis:						
CO, %	.0700	.0500	.0500	.0400	.0500	.0400
CO2, %	10.38	10.60	9.26	8.23	9.55	6.79
O2, %						
HC, ppmC	184	187	252	244	296	515
NOx, ppm	478	432	420	385	370	265
Emission rates, g/hr:						
CO	94.0	63.8	66.9	56.5	63.5	72.5
HC	12.4	12.0	16.9	17.3	18.9	46.9
NOx**	104.6	89.1	91.2	88.2	76.1	78.3
Oil temperature, F	178	180	174	167	190	182
Oil pressure, psi	44	43	45	45	42	44
Coolant temperature, F	191	191	190	191	191	191
Exhaust temperature, F	858	757	825	722	716	604
Exhaust pressure, in H2O	16.0	15.0	15.0	15.0	14.0	14.0
Exhaust flow, lb/min	5.64	5.36	5.56	5.81	5.29	7.37
Smoke, % opacity	14.5	9.5	11.0	8.0	8.5	4.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number................ Test Date..................	14 10/ 8/75	15 10/ 8/75	16 10/ 8/75	17 10/ 8/75	19 10/ 8/75	20 10/ 8/75
Barometer, mm Hg...........	739.2	739.2	739.2	739.2	739.2	739.2
Humidity, grains/lb........	83	83	83	83	83	83
Temperature, F.............	83	84	85	85	84	83
Engine speed, rpm..........	1200	1200	1200	1200	1200	1200
Torque, lb-ft..............	34.5	34.5	18.3	16.2	5.4	5.2
Power, bhp*................	8.0	8.0	4.3	3.8	1.3	1.2
Fuel rate, lb/hr...........	4.8	4.5	4.3	3.2	2.5	2.5
Throttle angle, deg........	2.9	2.9	2.2	2.2	2.0	2.0
Concentrations, dry basis:						
CO, %................	.0500	.0600	.0600	.0600	.0600	.0600
CO2, %...............	4.69	4.42	3.67	3.49	3.02	2.97
O2, %................						
HC, ppmC.............	403	306	406	335	247	331
NOx, ppm.............	142	146	95	105	96	87
Emission rates, g/hr:						
CO...................	57.5	71.1	84.0	71.9	67.5	69.6
HC...................	23.3	18.2	28.5	20.2	14.0	19.2
NOx**................	27.3	29.0	22.3	21.1	18.0	16.9
Oil temperature, F.........	169	170	167	168	169	167
Oil pressure, psi..........	43	43	44	45	43	43
Coolant temperature, F.....	188	187	191	188	192	188
Exhaust temperature, F.....	352	378	322	293	243	243
Exhaust pressure, in H2O...	7.0	7.0	9.0	7.0	6.0	6.0
Exhaust flow, lb/min.......	4.58	4.71	5.52	4.72	4.41	4.54
Smoke, % opacity...........	2.5	3.0	2.0	1.5	1.0	2.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine: Perkins diesel, 247-CID
Fuel: 7558

Test Number	21	22	23	24	25	26
Test Date	10/ 8/75	10/ 8/75	10/ 2/75	10/ 9/75	10/ 9/75	10/ 9/75
Barometer, mm Hg	739.2	739.2	755.5	746.5	746.5	746.5
Humidity, grains/lb	83	83	58	68	68	68
Temperature, F	84	86	91	86	84	84
Engine speed, rpm	1200	1200	1600	1600	1600	1600
Torque, lb-ft	0.0	0.0	177.0	163.2	146.6	130.8
Power, bhp*	0.0	0.0	53.9	50.1	44.9	40.1
Fuel rate, lb/hr	2.0	2.1	23.0	21.0	19.0	17.2
Throttle angle, deg	1.9	1.8	26.0	6.4	6.1	6.0
Concentrations, dry basis:						
CO, %	.0600	.0600	.1700	.0600	.0500	.0600
CO2, %	2.53	2.53	11.28	10.07	9.35	8.59
O2, %						
HC, ppmC	309	424	467	247	193	313
NOx, ppm	76	64	480	595	605	580
Emission rates, g/hr:						
CO	67.0	73.7	294.8	115.6	95.5	116.3
HC	17.3	26.1	40.6	23.9	18.5	30.4
NOx**	14.1	13.1	131.3	185.3	186.8	181.7
Oil temperature, F	168	173	176	175	173	173
Oil pressure, psi	47	44	46	47	47	47
Coolant temperature, F	188	190	192	192	192	191
Exhaust temperature, F	225	242	1051	953	858	782
Exhaust pressure, in H2O	6.0	7.0	24.0	29.0	27.0	25.0
Exhaust flow, lb/min	4.35	4.79	7.34	8.07	7.94	8.00
Smoke, % opacity	1.0	1.0	16.0	10.0	7.5	7.5

* Corrected - SAE J816b.

** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number.................	27	29	30	31	32	34
Test Date...................	10/ 9/75	10/ 8/75	10/ 8/75	10/ 8/75	10/ 2/75	10/ 8/75
Barometer, mm Hg............	746.5	739.2	739.2	739.2	755.5	739.2
Humidity, grains/lb.........	68	83	83	83	32	83
Temperature, F..............	81	83	83	86	81	86
Engine speed, rpm...........	1600	1600	1600	1600	1600	1600
Torque, lb-ft...............	130.6	88.1	87.1	37.4	34.1	27.3
Power, bhp*.................	39.9	27.3	27.0	11.6	10.2	8.5
Fuel rate, lb/hr............	18.8	12.5	12.8	7.2	7.0	6.2
Throttle angle, deg.........	6.0	5.0	5.0	3.3	3.2	3.0
Concentrations, dry basis:						
CO, %.....................	.0600	.0500	.0600	.0600	.0600	.0800
CO2, %....................	8.68	6.87	7.03	4.55	4.04	4.29
O2, %.....................						
HC, ppmC..................	308	405	466	572	767	711
NOx, ppm..................	585	360	365	204	180	139
Emission rates, g/hr:						
CO........................	118.3	98.2	115.1	110.3	113.6	144.4
HC........................	30.4	39.9	44.8	52.8	72.9	64.4
NOx**.....................	186.3	118.4	117.3	62.8	50.6	42.0
Oil temperature, F..........	163	173	171	175	169	175
Oil pressure, psi...........	47	47	47	47	47	47
Coolant temperature, F......	192	189	190	190	190	190
Exhaust temperature, F......	774	579	575	422	382	372
Exhaust pressure, in H20....	25.0	20.0	20.0	15.0	15.0	14.0
Exhaust flow, lb/min........	8.15	7.98	7.81	7.31	7.49	7.16
Smoke, % opacity............	6.0	4.0	3.5	2.5	3.0	1.5

* Corrected - SAE J816b.
** Corrected for humidity.

Engine....................... Perkins diesel, 247-CID
Fuel......................... 7558

Test Number	35	37	38	39	40	41
Test Date	10/ 8/75	10/ 8/75	10/ 8/75	10/ 8/75	10/ 2/75	10/ 7/75
Barometer, mm Hg	739.2	739.2	739.2	739.2	755.5	746.0
Humidity, grains/lb	83	83	83	83	58	72
Temperature, F	85	83	82	83	92	87
Engine speed, rpm	1600	1600	1600	1600	1900	1900
Torque, lb-ft	22.1	6.6	6.4	0.0	174.0	145.5
Power, bhp*	6.9	2.0	2.0	0.0	63.1	53.3
Fuel rate, lb/hr	6.0	5.0	5.0	4.5	28.0	23.0
Throttle angle, deg	3.0	2.6	2.6	2.6	26.0	9.5
Concentrations, dry basis:						
CO, %	.0900	.1000	.1000	.1200	.2000	.1000
CO2, %	4.04	3.31	3.19	2.85	11.51	10.17
O2, %						
HC, ppmC	796	1044	1072	1344	583	505
NOx, ppm	122	90	75	62	505	575
Emission rates, g/hr:						
CO	167.3	196.5	189.9	230.3	419.2	208.7
HC	74.3	103.0	102.2	129.5	61.3	52.9
NOx**	38.0	29.6	23.9	19.8	166.9	195.5
Oil temperature, F	174	171	171	172	179	175
Oil pressure, psi	47	47	47	47	46	46
Coolant temperature, F	188	188	189	189	192	190
Exhaust temperature, F	348	292	294	272	1119	979
Exhaust pressure, in H2O	15.0	15.0	15.0	15.0	31.0	33.0
Exhaust flow, lb/min	7.36	7.72	7.46	7.51	8.90	8.75
Smoke, % opacity	.5	2.0	1.0	1.0	14.0	8.5

* Corrected - SAE J816b.

** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number.................	42	43	45	46	47	48
Test Date...................	10/ 8/75	10/ 6/75	10/ 6/75	10/ 7/75	10/ 6/75	10/ 8/75
Barometer, mm Hg............	741.4	746.9	746.9	746.0	748.3	739.2
Humidity, grains/lb.........	70	69	69	72	69	83
Temperature, F..............	85	88	87	85	87	83
Engine speed, rpm...........	1900	1900	1900	1900	1900	1900
Torque, lb-ft...............	135.0	133.5	115.8	79.5	76.0	43.5
Power, bhp*.................	49.6	48.9	42.3	29.0	27.7	16.0
Fuel rate, lb/hr............	21.0	21.0	19.0	14.0	13.0	9.5
Throttle angle, deg.........	9.3	9.2	8.7	7.6	7.6	6.0
Concentrations, dry basis:						
CO, %.......................	.0800	.0800	.0700	.0500	.0600	.0600
CO2, %......................	9.06	10.55	9.55	6.40	7.20	5.02
O2, %.......................						
HC, ppmC....................	518	446	416	699	619	373
NOx, ppm....................	585	548	520	370	355	238
Emission rates, g/hr:						
CO..........................	169.3	167.7	147.0	110.1	126.9	128.4
HC..........................	55.0	46.9	43.9	77.3	65.7	40.1
NOx**.......................	200.9	185.8	176.7	132.8	121.4	85.3
Oil temperature, F..........	175	178	179	178	178	175
Oil pressure, psi...........	47	47	47	47	47	47
Coolant temperature, F......	191	193	191	190	190	190
Exhaust temperature, F......	905	897	820	641	609	470
Exhaust pressure, in H2O....	32.0	34.0	30.0	24.0	24.0	20.0
Exhaust flow, lb/min........	8.78	8.81	8.75	8.91	8.62	8.55
Smoke, % opacity............	6.0	5.0	6.0	4.0	3.0	2.5

* Corrected - SAE J816b.
** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number	49	54	55	56	57	58
Test Date	10/ 8/75	10/ 7/75	10/ 6/75	10/ 6/75	10/ 7/75	10/ 2/75
Barometer, mm Hg	739.2	746.0	748.3	748.3	746.0	754.5
Humidity, grains/lb	83	72	70	70	72	70
Temperature, F	86	84	85	82	84	82
Engine speed, rpm	1900	1900	1900	1900	1900	1900
Torque, lb-ft	32.8	14.8	12.9	6.8	6.0	0.0
Power, bhp*	12.1	5.4	4.7	2.4	2.2	0.0
Fuel rate, lb/hr	8.8	7.0	6.3	5.5	6.0	5.2
Throttle angle, deg	6.3	5.8	5.5	5.4	5.4	5.2
Concentrations, dry basis:						
CO, %	.0800	.1100	.1000	.1000	.1100	.1000
CO2, %	7.45	3.67	3.92	3.43	3.14	2.85
O2, %						
HC, ppmC	593	1084	1399	1282	957	1769
NOx, ppm	167	105	94	84	91	76
Emission rates, g/hr:						
CO	167.1	243.6	218.3	217.6	239.3	223.3
HC	62.2	120.5	153.2	140.1	104.5	198.3
NOx**	58.4	37.9	33.1	29.4	32.1	27.6
Oil temperature, F	179	184	181	173	179	174
Oil pressure, psi	47	45	46	47	45	47
Coolant temperature, F	188	190	189	188	189	187
Exhaust temperature, F	434	385	354	326	345	422
Exhaust pressure, in H20	20.0	20.0	21.0	20.0	19.0	20.0
Exhaust flow, lb/min	8.54	8.73	8.63	8.56	8.54	8.74
Smoke, % opacity	1.5	3.0	2.0	3.0	2.5	4.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number................	59	60	61	62	63	64
Test Date..................	10/ 2/75	10/ 2/75	10/ 7/75	10/ 8/75	10/ 7/75	10/ 8/75
Barometer, mm Hg...........	754.5	755.5	746.0	741.4	746.0	741.4
Humidity, grains/lb........	70	58	72	70	72	70
Temperature, F.............	82	92	87	86	83	83
Engine speed, rpm..........	1900	2100	2100	2100	2100	2100
Torque, lb-ft..............	0.0	171.0	151.2	135.8	133.0	121.5
Power, bhp*................	0.0	68.7	61.3	55.3	53.6	49.3
Fuel rate, lb/hr...........	5.0	32.0	26.5	24.0	24.0	21.5
Throttle angle, deg........	5.3	26.0	12.1	11.7	11.6	9.4
Concentrations, dry basis:						
CO, %......................	.1100	.1900	.1100	.0800	.0700	.0600
CO2, %.....................	2.74	11.51	10.28	8.97	9.26	8.50
O2, %......................						
HC, ppmC...................	1595	735	690	516	412	721
NOx, ppm...................	62	515	585	585	585	562
Emission rates, g/hr:						
CO.........................	244.0	462.0	268.6	196.7	173.2	148.5
HC.........................	177.6	89.6	84.5	63.6	51.2	89.5
NOx**......................	22.3	197.5	232.8	233.4	235.9	225.8
Oil temperature, F.........	173	183	180	180	180	179
Oil pressure, psi..........	47	47	46	47	47	47
Coolant temperature, F.....	187	193	192	192	191	192
Exhaust temperature, F.....	296	1169	1008	940	908	840
Exhaust pressure, in H2O...	19.0	37.0	42.0	40.0	42.0	38.0
Exhaust flow, lb/min.......	8.67	10.32	10.25	10.19	10.28	10.21
Smoke, % opacity...........	3.0	13.0	8.0	6.0	4.0	4.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine: Perkins diesel, 247-CID
Fuel: 7558

Test Number	65	66	67	68	69	74
Test Date	10/ 6/75	10/ 6/75	10/ 7/75	10/ 8/75	10/ 2/75	10/ 6/75
Barometer, mm Hg	746.9	748.3	746.0	739.2	755.5	748.3
Humidity, grains/lb	69	69	72	83	70	70
Temperature, F	87	87	85	86	82	84
Engine speed, rpm	2100	2100	2100	2100	2100	2100
Torque, lb-ft	119.2	80.2	79.4	52.5	49.5	15.6
Power, bhp*	48.2	32.4	32.1	21.5	19.7	6.3
Fuel rate, lb/hr	21.3	15.5	16.0	12.0	12.5	8.2
Throttle angle, deg	11.3	10.0	10.0	9.4	9.3	8.4
Concentrations, dry basis:						
CO, %	.0600	.0500	.0500	.0600	.0500	.1000
CO2, %	9.55	7.20	6.40	5.23	4.82	4.04
O2, %						
HC, ppmC	359	346	293	287	433	1621
NOx, ppm	508	345	375	275	255	90
Emission rates, g/hr:						
CO	144.7	123.9	125.6	148.2	129.1	251.6
HC	43.5	43.1	36.9	35.6	56.1	204.7
NOx**	198.2	138.3	153.5	113.7	106.9	36.7
Oil temperature, F	181	181	179	179	175	179
Oil pressure, psi	47	47	47	47	47	47
Coolant temperature, F	192	190	190	189	190	190
Exhaust temperature, F	841	641	658	496	490	381
Exhaust pressure, in H2O	48.0	32.0	31.0	27.0	29.0	26.0
Exhaust flow, lb/min	10.05	10.11	10.16	9.88	10.30	9.96
Smoke, % opacity	4.5	2.0	3.0	3.0	3.0	3.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number Test Date	75 10/ 7/75	76 10/ 6/75	77 10/ 7/75	78 10/ 2/75	79 10/ 2/75	80 10/ 2/75
Barometer, mm Hg	746.0	748.3	746.0	754.5	754.5	755.5
Humidity, grains/lb	72	70	72	70	70	58
Temperature, F	83	82	82	81	82	99
Engine speed, rpm	2100	2100	2100	2100	2100	2400
Torque, lb-ft	13.8	8.7	6.2	0.0	0.0	168.0
Power, bhp*	5.6	3.5	2.5	0.0	0.0	77.1
Fuel rate, lb/hr	8.2	7.3	7.2	6.2	6.3	35.0
Throttle angle, deg	8.3	8.2	8.1	8.0	8.0	26.0
Concentrations, dry basis:						
CO, %	.1000	.1000	.1100	.1000	.1000	.1700
CO2, %	3.67	3.57	3.31	2.85	2.97	11.30
O2, %						
HC, ppmC	1219	1669	924	1631	1923	453
NOx, ppm	115	90	115	72	78	495
Emission rates, g/hr:						
CO	253.2	256.7	279.9	255.1	256.7	466.2
HC	154.9	215.0	118.1	208.9	247.7	62.4
NOx**	47.5	37.4	47.7	29.8	32.3	214.1
Oil temperature, F	179	177	170	176	178	192
Oil pressure, psi	48	50	49	49	50	48
Coolant temperature, F	190	190	188	188	188	193
Exhaust temperature, F	404	342	333	303	432	1218
Exhaust pressure, in H2O	26.0	26.0	24.0	25.0	25.0	46.0
Exhaust flow, lb/min	9.99	10.11	10.00	9.98	10.06	11.62
Smoke, % opacity	3.0	3.0	2.5	3.5	4.0	13.0

* Corrected - SAE J816b.

** Corrected for humidity.

Engine: Perkins diesel, 247-CID
Fuel: 7558

Test Number	81	82	83	84	85	86
Test Date	10/ 7/75	10/ 8/75	10/ 7/75	10/ 8/75	10/ 6/75	10/ 7/75
Barometer, mm Hg	746.0	741.4	746.0	741.4	746.9	746.0
Humidity, grains/lb	72	70	72	70	69	72
Temperature, F	88	89	85	84	87	85
Engine speed, rpm	2400	2400	2400	2400	2400	2400
Torque, lb-ft	151.3	137.3	136.1	122.0	119.9	82.4
Power, bhp*	70.3	64.2	63.0	56.7	55.5	38.1
Fuel rate, lb/hr	30.0	28.0	28.0	25.0	25.0	19.0
Throttle angle, deg	14.6	14.4	14.4	14.0	14.0	13.0
Concentrations, dry basis:						
CO, %	.1000	.0600	.0600	.0600	.0600	.0500
CO2, %	10.38	9.35	9.55	8.68	9.76	6.56
O2, %						
HC, ppmC	494	370	348	294	306	361
NOx, ppm	575	590	585	548	508	395
Emission rates, g/hr:						
CO	271.4	161.8	166.0	165.6	164.7	138.3
HC	67.2	50.0	48.4	40.7	42.2	50.2
NOx**	254.3	258.2	263.7	245.5	225.6	178.1
Oil temperature, F	184	191	184	183	185	183
Oil pressure, psi	48	46	47	49	49	49
Coolant temperature, F	193	193	192	192	192	192
Exhaust temperature, F	1092	1076	997	984	880	791
Exhaust pressure, in H2O	55.0	54.0	53.0	50.0	49.0	42.0
Exhaust flow, lb/min	11.40	11.21	11.53	11.41	11.46	11.21
Smoke, % opacity	6.5	6.0	3.5	3.5	4.0	2.5

* Corrected - SAE J816b.
** Corrected for humidity.

Engine...................... Perkins diesel, 247-CID
Fuel........................ 7558

Test Number.................	87	89	90	94	95	96
Test Date...................	10/ 6/75	10/ 2/75	10/ 2/75	10/ 7/75	10/ 6/75	10/ 7/75
Barometer, mm Hg............	748.3	755.5	755.5	746.0	748.3	746.0
Humidity, grains/lb.........	69	70	70	72	69	72
Temperature, F..............	86	82	85	83	84	82
Engine speed, rpm...........	2400	2400	2400	2400	2400	2400
Torque, lb-ft...............	79.3	58.7	45.4	15.4	14.9	7.7
Power, bhp*.................	36.6	26.7	20.8	7.1	6.9	3.5
Fuel rate, lb/hr............	18.5	16.0	14.0	10.5	9.8	9.2
Throttle angle, deg.........	13.0	12.5	12.2	11.4	11.4	11.2
Concentrations, dry basis:						
CO, %.................	.0600	.0500	.0600	.0900	.1000	.1100
CO2, %................	7.53	5.37	5.09	3.92	4.23	3.55
O2, %.................						
HC, ppmC..............	507	665	792	1501	1900	1341
NOx, ppm..............	360	300	225	138	90	115
Emission rates, g/hr:						
CO....................	166.2	144.7	172.4	254.7	280.6	313.0
HC....................	70.4	96.6	114.2	213.3	267.6	191.5
NOx**.................	161.3	140.9	104.9	63.6	40.9	53.3
Oil temperature, F..........	181	179	186	175	183	179
Oil pressure, psi...........	50	50	49	50	48	49
Coolant temperature, F......	191	192	189	190	190	190
Exhaust temperature, F......	742	604	566	449	419	401
Exhaust pressure, in H2O....	42.0	39.0	37.0	32.0	0.0	31.0
Exhaust flow, lb/min........	11.33	11.60	11.49	11.19	11.13	11.21
Smoke, % opacity............	3.0	3.0	3.0	2.0	2.0	3.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number	97	98	99	111	112	113
Test Date	10/ 6/75	10/ 2/75	10/ 2/75	10/ 2/75	10/ 7/75	10/ 7/75
Barometer, mm Hg	748.3	754.5	754.5	755.5	746.0	746.0
Humidity, grains/lb	70	70	70	58	72	72
Temperature, F	82	81	83	99	88	86
Engine speed, rpm	2400	2400	2400	3000	3000	3000
Torque, lb-ft	7.2	0.0	0.0	160.1	140.5	130.1
Power, bhp*	3.3	0.0	0.0	93.2	81.9	75.6
Fuel rate, lb/hr	8.8	8.0	8.0	45.0	39.0	35.0
Throttle angle, deg	11.2	11.0	11.0	26.0	19.6	19.5
Concentrations, dry basis:						
CO, %	.1000	.0900	.1000	.2100	.1100	.0800
CO2, %	3.79	3.08	3.19	11.05	10.60	9.76
O2, %						
HC, ppmC	2112	1831	2213	794	942	473
NOx, ppm	64	82	85	530	632	640
Emission rates, g/hr:						
CO	281.2	267.8	290.6	720.6	372.2	272.4
HC	298.1	273.4	322.8	136.7	159.9	80.9
NOx**	29.2	39.6	39.9	286.8	348.4	355.1
Oil temperature, F	180	179	182	201	193	191
Oil pressure, psi	50	50	50	52	52	53
Coolant temperature, F	189	189	188	194	193	192
Exhaust temperature, F	485	358	423	1306	1137	1027
Exhaust pressure, in H2O	32.0	32.0	33.0	69.0	87.0	83.0
Exhaust flow, lb/min	11.10	11.67	11.41	14.51	14.24	14.22
Smoke, % opacity	3.0	3.0	4.0	8.0	3.0	3.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine...................... Perkins diesel, 247-CID
Fuel........................ 7558

Test Number.................	114	115	116	117	118	121
Test Date...................	10/ 8/75	10/ 6/75	10/ 8/75	10/ 8/75	10/ 2/75	10/ 2/75
Barometer, mm Hg............	741.4	746.9	741.4	739.2	755.5	754.5
Humidity, grains/lb.........	70	69	70	83	70	70
Temperature, F..............	87	87	84	88	84	83
Engine speed, rpm...........	3000	3000	3000	3000	3000	3000
Torque, lb-ft...............	126.8	109.4	108.0	84.6	82.8	45.3
Power, bhp*.................	74.2	63.6	63.0	49.9	47.5	26.0
Fuel rate, lb/hr............	35.0	30.5	31.0	26.2	26.7	20.0
Throttle angle, deg.........	19.6	18.8	19.0	18.4	18.3	17.5
Concentrations, dry basis:						
CO, %................	.0800	.0700	.0600	.0800	.0600	.0800
CO2, %...............	9.45	9.76	8.23	7.70	6.56	5.51
O2, %................						
HC, ppmC.............	555	320	269	842	655	1967
NOx, ppm.............	640	520	530	405	390	230
Emission rates, g/hr:						
CO...................	271.5	238.1	206.9	273.1	211.0	279.6
HC...................	94.6	54.6	46.5	144.2	115.5	345.0
NOx**................	352.6	286.2	296.7	231.6	222.5	130.5
Oil temperature, F..........	190	194	191	195	192	191
Oil pressure, psi...........	50	53	54	54	53	53
Coolant temperature, F......	192	192	193	191	193	191
Exhaust temperature, F......	1063	930	954	836	785	630
Exhaust pressure, in H20....	80.0	77.0	73.0	66.0	69.0	58.0
Exhaust flow, lb/min........	14.13	14.20	14.20	13.99	14.25	14.03
Smoke, % opacity............	2.5	2.5	2.0	2.5	2.0	3.5

* Corrected - SAE J816b.
** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number	122	123	124	125	126	127
Test Date	10/ 8/75	10/ 7/75	10/ 6/75	10/ 6/75	10/ 7/75	10/ 2/75
Barometer, mm Hg	739.2	746.0	748.3	748.3	746.0	754.5
Humidity, grains/lb	83	72	69	70	72	70
Temperature, F	85	83	85	84	83	81
Engine speed, rpm	3000	3000	3000	3000	3000	3000
Torque, lb-ft	45.0	15.4	13.4	8.3	6.0	0.0
Power, bhp*	26.4	8.9	7.8	4.8	3.5	0.0
Fuel rate, lb/hr	20.0	15.5	14.0	13.5	13.8	12.0
Throttle angle, deg	17.5	16.9	16.9	16.7	16.6	16.5
Concentrations, dry basis:						
CO, %	.1000	.0900	.1000	.1100	.1100	.1000
CO2, %	6.10	4.42	4.82	4.42	4.04	3.55
O2, %						
HC, ppmC	2335	2117	2177	2545	1862	2243
NOx, ppm	212	117	100	91	98	80
Emission rates, g/hr:						
CO	344.0	317.7	336.3	384.8	386.5	344.6
HC	403.0	375.1	367.5	446.9	328.2	388.0
NOx**	122.1	67.3	54.4	51.3	56.1	44.7
Oil temperature, F	192	189	191	192	189	189
Oil pressure, psi	50	50	49	50	50	53
Coolant temperature, F	191	190	191	190	190	189
Exhaust temperature, F	628	512	496	467	449	438
Exhaust pressure, in H2O	55.0	52.0	51.0	51.0	50.0	48.0
Exhaust flow, lb/min	13.88	14.03	13.41	13.90	13.91	13.58
Smoke, % opacity	3.0	4.0	2.5	3.5	2.5	5.0

* Corrected - SAE J816b.

** Corrected for humidity.

Engine........................ Perkins diesel, 247-CID
Fuel.......................... 7558

Test Number................	128	140	141	142	143	144
Test Date..................	10/ 2/75	10/ 2/75	10/ 7/75	10/ 8/75	10/ 7/75	10/ 2/75
Barometer, mm Hg...........	754.5	755.5	746.0	739.2	746.0	755.5
Humidity, grains/lb........	70	58	72	83	72	70
Temperature, F.............	82	90	90	93	87	89
Engine speed, rpm..........	3000	3600	3600	3600	3600	3600
Torque, lb-ft..............	0.0	144.0	130.5	115.9	115.5	110.0
Power, bhp*................	0.0	99.9	91.8	82.8	80.9	76.4
Fuel rate, lb/hr...........	12.4	51.0	48.0	44.0	44.0	42.5
Throttle angle, deg........	16.5	26.0	25.2	24.6	24.8	24.5
Concentrations, dry basis:						
CO, %..................	.1250	.1400	.1300	.1200	.1300	.1200
CO2, %.................	3.67	10.83	11.05	10.38	10.17	9.55
O2, %..................						
HC, ppmC...............	2408	465	599	499	677	550
NOx, ppm...............	83	545	530	495	515	500
Emission rates, g/hr:						
CO.....................	444.9	552.3	507.1	463.1	510.7	476.2
HC.....................	430.2	92.0	117.3	96.7	133.5	109.6
NOx**..................	48.0	339.1	336.9	319.9	329.7	322.0
Oil temperature, F.........	192	199	203	206	202	203
Oil pressure, psi..........	53	53	52	52	53	54
Coolant temperature, F.....	190	195	194	193	193	194
Exhaust temperature, F.....	427	1350	1286	1220	1193	1156
Exhaust pressure, in H2O...	50.0	94.0	123.0	113.0	116.0	116.0
Exhaust flow, lb/min.......	14.04	16.64	16.48	16.21	16.47	16.54
Smoke, % opacity...........	5.5	7.0	3.0	3.5	3.0	4.0

* Corrected - SAE J816b.
** Corrected for humidity.

Engine: Perkins diesel, 247-CID
Fuel: 7558

Test Number	145	149	150	153	154	155
Test Date	10/ 8/75	10/ 7/75	10/ 6/75	10/ 6/75	10/ 7/75	10/ 6/75
Barometer, mm Hg	741.4	746.0	748.3	748.3	746.0	748.3
Humidity, grains/lb	70	72	69	69	72	69
Temperature, F	86	86	85	86	84	86
Engine speed, rpm	3600	3600	3600	3600	3600	3600
Torque, lb-ft	102.6	69.4	66.4	33.0	32.8	16.6
Power, bhp*	72.2	48.6	46.3	23.0	22.9	11.6
Fuel rate, lb/hr	39.0	32.0	31.5	24.0	24.0	20.0
Throttle angle, deg	24.3	24.0	24.0	23.5	23.5	23.0
Concentrations, dry basis:						
CO, %	.1600	.1300	.1400	.1100	.1100	.1300
CO2, %	9.35	7.36	8.59	6.87	5.95	5.95
O2, %						
HC, ppmC	740	1111	1428	1506	1405	1876
NOx, ppm	450	290	282	160	160	110
Emission rates, g/hr:						
CO	626.2	517.7	548.0	433.0	436.7	511.0
HC	145.4	222.1	280.6	297.5	279.9	370.1
NOx**	285.9	188.2	178.6	101.9	103.5	69.9
Oil temperature, F	201	192	190	201	196	201
Oil pressure, psi	53	54	55	58	49	53
Coolant temperature, F	193	192	193	192	192	192
Exhaust temperature, F	1124	959	900	756	773	695
Exhaust pressure, in H2O	107.0	95.0	96.0	83.0	80.0	77.0
Exhaust flow, lb/min	16.29	16.27	16.18	16.01	16.00	15.85
Smoke, % opacity	3.0	3.0	2.5	2.5	3.0	2.5

* Corrected - SAE J816b.
** Corrected for humidity.

Engine...................... Perkins diesel, 247-CID
Fuel........................ 7558

Test Number................	156	157	158	159	160
Test Date..................	10/ 7/75	10/ 6/75	10/ 7/75	10/ 2/75	10/ 2/75
Barometer, mm Hg...........	746.0	748.3	746.0	754.5	754.5
Humidity, grains/lb........	72	70	72	70	70
Temperature, F.............	85	85	84	83	84
Engine speed, rpm..........	3600	3600	3600	3600	3600
Torque, lb-ft..............	13.5	8.4	6.0	0.0	0.0
Power, bhp*................	9.4	5.9	4.2	0.0	0.0
Fuel rate, lb/hr...........	20.5	19.3	19.0	18.0	18.0
Throttle angle, deg........	22.8	22.5	22.4	22.0	22.0
Concentrations, dry basis:					
CO, %..................	.1200	.1300	.1300	.1400	.1300
CO2, %.................	5.09	5.51	4.89	4.42	4.55
O2, %..................					
HC, ppmC...............	1609	1666	1584	2007	2044
NOx, ppm...............	108	94	91	75	78
Emission rates, g/hr:					
CO.....................	474.4	511.5	512.9	579.9	534.3
HC.....................	319.3	329.1	313.7	417.2	421.6
NOx**..................	69.6	59.9	58.2	50.4	51.7
Oil temperature, F.........	199	196	200	199	200
Oil pressure, psi..........	48	54	53	53	53
Coolant temperature, F.....	191	192	191	191	191
Exhaust temperature, F.....	698	657	651	610	610
Exhaust pressure, in H2O...	75.0	76.0	72.0	73.0	73.0
Exhaust flow, lb/min.......	15.81	15.80	15.75	16.46	16.35
Smoke, % opacity...........	4.0	3.0	3.0	5.5	5.0

* Corrected - SAE J816b.
** Corrected for humidity.

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